

METHOD FOR SENDING NOTICE OF FAILURE DETECTION

BACKGROUND OF THE INVENTION

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This invention relates to a method for sending a notice of failure detection. More particularly, this invention relates to a method for sending a notice of failure detection in a system wherein apparatuses A and B are connected by a pair of two independent transfer paths, that is, a transfer path for transmitting data from the apparatus A to the apparatus B and a transfer path for transmitting the data from the apparatus B to the apparatus A, and the data are communicated mutually between these two apparatuses.

In apparatuses for executing data communication by using twist-pair cables or optical fiber cables in accordance with the system stipulated by IEEE802.3 (IEEE: The Institute of Electrical and Electronics Engineers), two apparatuses are point-to-point connected by one cable. The term "apparatus" used hereby means an inter-network apparatus such as a computer, a hub accommodating therein a computer, a router, a LAN switch, and so forth. Let's consider, for example, a case where computers are accommodated in a network connection apparatus called "a LAN switch" by using twist-pair cables. When two apparatuses are called hereby the "apparatus A" and "apparatus B", the cable that connects these apparatuses A and B includes a

15 The communication system described above has a
setup for detecting whether or not the two apparatus
connected by the cables are under the communicable
condition. In other words, the apparatus A not only
transmits data to the transfer path for transmitting the
20 data to the apparatus B but transmits either periodically
or steadily a specific signal different from the data
during the period in which it does not transmit the data.
On the other hand, the apparatus B always monitors the
transfer path for receiving the data, detects the data or
25 the specific signal different from the data transmitted
from the apparatus A and thus confirms that data can be
transmitted from the apparatus A to the apparatus B. A
signal called "link pulse" is mainly used in the system

using the twist-pair cable. In a system that uses the optical fiber cable, there is a method that utilizes an idle signal sent for reproducing the reception clocks. Receiving these signals, the apparatus B can know whether
5 or not the apparatus A and the transfer path for transmitting the data from the apparatus A to the apparatus B operate normally. A similar processing is executed, too, on the transfer path for transmitting data from the apparatus B to the apparatus A. In consequence, it is
10 possible to know that the transfer paths between the apparatus A and the apparatus B are connected correctly and that no failure occurs in the mating apparatus, hence the apparatuses A and B are under the communicable condition.

SUMMARY OF THE INVENTION

15 In the background art technologies, the apparatus A monitors the signals of a transfer path for receiving data transmitted from the apparatus B. Therefore, the apparatus A can know a failure of the transfer path for transmitting data from the apparatus B to the apparatus A
20 when it detects the non-arrival of a signal from the apparatus B. However, the apparatus A cannot detect by itself a failure of the transfer path for transmitting data from the apparatus A to the apparatus B. IEEE802.3 defines, as "remote failure report function of auto-
25 negotiation", means for reporting a failure to the apparatus A by modifying a signal to be sent to the transfer path for transmitting data to the apparatus A when the

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~~that point-to-point connect the two apparatuses.~~ 41)

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The present invention uses the function of examining whether or not the line operates normally, which function is supported by all the apparatuses when the failure is reported to the mating apparatus. Therefore, the present invention does not spoil mutual connectivity with existing apparatuses. Even when the present invention is applied, a specific control frame need not be exchanged between the apparatuses connected to each other. Therefore, a new protocol need not be prepared, either, and the present system can be accomplished merely by the simple operation.

When the apparatuses according to the present invention are employed to constitute a dual system, the whole system can be switched at a high speed and reliably even when any failure occurs at only a limited part of the lines between the apparatuses.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example of an apparatus equipped with a line failure detection/reporting system according to the first embodiment of the present invention, and an example of a communication system using the apparatus;

Fig. 2 is flowchart showing a processing flow of the apparatus equipped with the line failure detection/reporting system from turn-on of a power source of the apparatus to a normal operation start condition or an

reporting system according to the second embodiment detects the failure of its own interface;

Fig. 10 is a flowchart showing an example of the processing flow from the normal operation condition to the operation stop condition when the line failure detection/ reporting system according to the second embodiment detects a failure of another interface belonging to the same group and stops the operation;

Fig. 11 is a flowchart showing a processing flow of a higher layer control portion when the whole circuit control portion belonging to the group including a failure- occurring line reaches the operation stop condition in the failure detection/reporting system according to the second embodiment;

Fig. 12 is a flowchart showing a processing flow of the higher control portion when the whole circuit control portion returns to the operation condition as the failure in the failure-occurring line as the cause of the operation stop of the overall group is eliminated, in the line failure detection/reporting system according to the present invention; and

Fig. 13 shows a structural example of a table of group storage means in the line failure detection/reporting system according to the second embodiment.

25 DESCRIPTION OF THE EMBODIMENTS

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~~The first embodiment of the present invention will be explained. In this embodiment, one cable~~

~~LAN switches, and so forth.~~

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The function of the higher layer control portion 1016 (1116) may be selected appropriately depending on what kind of apparatuses the apparatus A1000 (B1100) is. When the apparatus A (B) is a computer, for example, the higher layer control portion 1016 (1116) has an arithmetic unit and storage means, and has a protocol control function for controlling the data transmission/reception to and from the interface 1010 (1110). When the apparatus A (B) is an inter-network apparatus, for example, the higher layer control portion 1016 (1116) has a relay engine, for example, and a function of relaying the data received from the interface 1010 (1116) to another interface. In either case, the higher layer control portion 1016 (1116) may have the functions of receiving a failure notice from the line control portion 1014 (1114) and executing a corresponding processing when a mating apparatus 1100 (1110) or a line 1200 that connects the higher layer control portion 1016 (1116) to the mating apparatus does not operate normally. The data transmission/reception control portion 1015 (1115) is interposed between the physical layer control portion 1011 (1111) and the higher layer control portion 1016 (1116) and controls the function that corresponds to a MAC (Media Access Control) layer.

A transmission control portion 1013 (1113) inside the physical layer control portion 1011 (1111) encodes the data it receives from the data transmission/reception

control portion 1015 (1115) in accordance with the specification of the physical layer and then outputs the data to the line 1200. On the contrary, the reception control portion 1012 (1112) executes decoding of the signal it receives from the line 1200, in accordance with the specification of the physical layer and delivers the resulting data to the data transmission/reception control portion 1015 (1115). Depending on the property of the transfer path 1201 (1202), the transmission control portion 1013 (1113) has the function of sending the signals (various control signals) that are not the data, such as a signal for confirming connectivity with the transfer path 1201 on the mating apparatus side, a signal directed to send clocks used in the physical layer control portion 1111 of the mating apparatus, etc., in accordance with the instruction of the circuit control portion 1014 (1114) during the period in which the data is not sent. The reception control portion 1012 (1112) has the functions of confirming utilizability of the transfer path, the apparatus by receiving the signal for confirming connectivity and the signal for sending the clocks flowing the transfer path 1202, confirming connectivity with the mating apparatus, the existence/absence of a failure in the transfer path or in the apparatus, and reporting the confirmation result to the line control portion 1014 (1114). In the 10 Base-T technology that uses a twist-pair cable for the line 1200, for example, the signal (control signal) described above, that is not the data, corresponds

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5 in which the data is not transmitted.

The line control portion 1014 (or 1114) has the functions of receiving the connectivity confirmation information with the mating apparatus from the reception control portion 1012 (1112) and giving the instruction to transmit the signal for confirming connectivity to the

The line control portion 1014 (or 1114) has the functions of receiving the connectivity confirmation information with the mating apparatus from the reception control portion 1012 (1112) and giving the instruction to transmit the signal for confirming connectivity to the

transfer path 1201 (1202) on the side of the mating apparatus and the clocks used in the physical layer control portion 1111 (1022) of the mating apparatus to the transmitting control portion 1013 (1113).

5 In the embodiment, the explanation will be given
on only the case where the interface 101 of the apparatus
A10000 is connected to the interface 1110 of the apparatus
B1100 by the line 1200 and data communication is executed,
but the present invention is not limited to such a case.

10 The operations of the interfaces of the apparatuses A1000 and B1000 other than the operation described above are not limited in this embodiment. In other words, the same processing as that of the present embodiment, or other processing, may be executed.

15 Next, the procedure for detecting a failure of
the line 1200 by the apparatus A1000 (B1100) will be
explained.

First, the procedure of turn-on of the power source from the condition where the power sources of both apparatuses are cut off will be explained with reference to Fig. 2. This flowchart shows step-wise the processing sequence from turn-on of the power sources of the apparatuses to the normal operation start condition or to the normal operation stop condition in the line failure detection/reporting system of the present invention. In this case, since the apparatus A and the apparatus B operate in exactly the same way, only the operation of the apparatus A1000 will be explained as a representative

First, when the power source is turned on (Step 2001), the line control portion 1014 instructs the transmission control portion 1013 of the physical layer control portion 1011 to transmit the link-up signal to the connecting mating apparatus B1100. Receiving this instruction, the transmission control portion 1013 starts transmitting the link-up signal to the connecting mating apparatus B1100 (Step 2002). The line control portion 1014 then activates

Next, the following judgment is made in accordance with the result of Step 2003 (Step 2004). When the link-up signal is received, this reception is notified to

the line control portion 1014. Judging that the preparation for transmitting and receiving the data is ready in the interface 1110 of the mating apparatus B1100 and in the line 1200, the line control portion 1014 stops the start
5 timer 1017 activated in Step 2008 (Step 2009). The interface 1010 then enters the normal operation condition (Step 2005). However, monitor of the later-appearing operation condition is not yet conducted at this point of time. After the passage of the predetermined time, the
10 monitor operation is started to monitor the normal operation condition (Step 3001). This predetermined time is called hereby the "insensitive time", and the reason why this insensitive time is necessary will be explained later.

If the link-up signal is not yet received in Step
15 2004, the flow proceeds to next Step 2006 as the preparation is not ready. In this Step 2006, whether or not the time of the start timer 1017 activated in Step 2008 is up is checked. When the time is up, the preparation of the interface 1110 of the mating apparatus B1100 or the
20 preparation of the line 1200 is judged as being not yet completed even though a sufficient time has passed. The start timer activated in Step 2008 is stopped (Step 2009), and the interface 101 enters the operation stop condition (Step 2007). However, monitor of the later-appearing
25 operation condition is not yet conducted at this point in Step 2007. After the passage of the predetermined time, monitor of the operation condition is executed even in the operation stop mode (Step 4001). This predetermined time

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5 of the processing, and the process steps described so far
are repeated.

control portion 1014 (1113) keeps transmitting the link-up signal for a predetermined time. In this way, the normal operation can be executed as soon as the preparation of the mating apparatus 1100 (1000) and the line 1200 becomes ready.

15 Referring next to Fig. 3, the explanation will be
given on the failure detection procedure when any failure
occurs in the transfer path 1202 for transmitting the data
from the apparatus B1100 to the apparatus A1000 or in the
transmission control portion 1113 of the apparatus B1100
20 and data communication becomes infeasible after both
apparatuses A and B start operating normally. Fig. 3 shows
an example of the processing procedure from the start of
the normal operation to the operation stop condition as a
failure is detected. The drawing shows the processing
25 procedure of only the apparatus A1000 because both
apparatuses A1000 and B1100 have originally the same
function, and the processing procedure of the apparatus
B1100 is the same as that of the apparatus A1000.

First, the explanation will be given from the point of time at which the apparatus A1000 enters the normal operation condition (Step 3001 in Figs. 2 and 3). After this Step 3001, the line control portion 1014 checks the condition of the reception control portion 1012 of the physical layer control portion 1011, and confirms whether or not the link-up signal is received through the transfer path 1202 (Step 3003). Next judgment is made in accordance with the result of Step 3003 (Step 3004). In other words, when the link-up signal is received, the line control portion 1014 judges that the interface 1110 of the mating apparatus B1100 and the line 1200 can consecutively transfer the data, and after the passage of a predetermined time (Step 3005), returns to Step 3003.

When the link-up signal is not yet received in Step 3004, the line control portion 1014 judges that any failure occurs in the interface 1110 of the mating apparatus B1100 and in the line 1200 and the data communication cannot be continued, and switches the processing to Step 3006. In this Step 3006, the reception control portion 1012 notifies the line control portion 1014 that it cannot receive the link-up signal any longer (or the line control portion 1014 judges the failure of the data communication from the condition of the reception control portion 1012). Receiving this notice, the line control portion 1014 instructs the transmission control portion 1013 to stop sending the link-up signal (Step 3007). The transmission control portion 1013 stops sending the link-up

10 In Step 3005, the reason why it is necessary to
wait for the predetermined time is as follows. The link-up
signal is the signal that is periodically transmitted from
the transmission control portion 1113, and a predetermined
time is necessary before the reception control portion 1012
15 detects the state where these link-up signals are no longer
received. The 10 Base-T technology using the twist-pair
cable, for example, stipulates this predetermined time as
50 to 150 milliseconds. Therefore, if the loop of Steps
3003, 3004 and 3005 can be executed within a sufficiently
20 shorter time than this time such as about 10 msec, it is
possible to detect instantaneously that the link-up signal
is no longer detected. Therefore, the loop need not be
executed at a higher speed.

On the other hand, the apparatus B1100, too,
25 executes the same processing as that of the apparatus A.
The apparatus B1100 cannot directly detect the failure of
the transfer path 1202. However, it can detect eventually
the failure of the transfer path 1202 as the apparatus

A1000 detects the failure of the transfer path 1202 and stops sending the link-up signal to the transfer path 1201. Consequently, the interface 1110 of the apparatus B enters the operation stop condition.

5 When the apparatus A (or the apparatus B) detects
the occurrence of the failure in one of the transfer paths
1202 (1201) as described above, the apparatus A (B)
compulsively stops sending the link-up signal to be sent to
the other transfer path 1201 (1202). In consequence, the
10 interfaces 1010 and 1110 of both apparatuses A1000 and
B1100 can detect the failure when any failure occurs even
at a part of the line 1200. When the cause of the failure
is thereafter removed and the operation can restore the
normal operation, the operation restores the normal
15 operation either automatically, or manually through an
operator, depending on the operation method of the
apparatus. The explanation will be given first on the
procedure of the automatic restoration.

The processing procedure when the apparatuses
20 A1000 and B1100 are so set as to achieve the automatic
restoration will be explained with reference to Fig. 4.
The drawing is a flowchart showing an example of the
processing procedure from the operation stop condition to
the normal operation start condition in the line failure
25 detection/reporting system according to the present
invention. First, it will be assumed that both Step 4001
of the apparatus A and Step 4101 of the apparatus B reach
the operation stop condition of Step 4001 as a result of

the processing shown in Fig. 2 or the operation stop condition of Step 4001 as a result of the processing shown in Fig. 3.

In the apparatus A, first of all, the line control portion 1014 instructs the transmission control portion 1013 of the physical layer control portion 1011 to start transmission of the link-up signal after Step 4001 (Step 4003). The transmission control portion 1013 starts transmitting the link-up signal in accordance the instruction (Step 4004). Thereafter, the passage of the predetermined time is waited again (Step 4005). This predetermined time is equal to the insensitive time described above. The line control portion 1014 examines the condition of the reception control portion 1012, and confirms whether or not it receives the link-up signal from the transfer path 1202 (Step 4006).

Next, the following judgment is made in accordance with the result of Step 4006 (Step 4007). When the link-up signal is received, a failure that has occurred in the interface 1110 of the mating apparatus B1100 or in the line 1200 is judged as being solved and the operation is judged as returning to the normal condition where the data communication can be made, and the apparatus A then returns to the normal operation condition (Step 4008). This Step 4008 is the same as Step 2005 shown in Fig. 2. After the passage of the insensitive time, the flow proceeds to Step 4009 (that is the same as Step 3001 in Fig. 2).

When the link-up signal is not received in Step

4007, the failure that has occurred in either the interface 1110 of the mating apparatus B1100 or the line 1200 is judged as being not yet solved and the data communication is judged as being impossible. Therefore, the flow
5 proceeds to Step 4011. In this Step 4011, the circuit control portion 1014 instructs the transmission control portion 103 to stop sending the link-up signal. In consequence, the transmission control portion 1013 stops transmitting the link-up signal (Step 4010). After the
10 passage of a predetermined time (Step 4002), the flow returns to Step 4003. This predetermined time is equal to the insensitive time described above.

The apparatus B1100 executes the following processing in parallel with the processing of the apparatus
15 A1000. First, the circuit control portion 1114 examines the condition of the reception control portion 1112, and confirms whether or not it receives the link-up signal from the transfer path 1201 (Step 4103). The following judgment is then made in accordance with the result of Step 4103
20 (Step 4104). When the link-up signal is received, the failure that has occurred in either the interface 1010 of the mating apparatus A1000 or the line 1200 is judged as being solved and the operation condition is judged as restored to the normal condition where the data communica-
25 tion can be made. The flow proceeds to Step 4106. In this Step 4106, the line control portion 1114 instructs the transmission control portion 1113 to start sending the link-up signal. The transmission control portion 1113

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5 After the passage of the insensitive time, the flow proceeds to Step 4109 (that is the same as Step 3001 in Fig. 2).

When the link-up signal is not received in Step 4104, the failure that has occurred in either the interface 1010 of the mating apparatus A1000 or the line 1200 remains unsolved and the data communication is judged as being not yet possible, the flow proceeds to Step 4105. After the passage of a predetermined time in Step 4105, the flow proceeds to Step 4103. The reason why the predetermined time is necessary is as follows. The link-up signal is the signal that is periodically transmitted from the transmission control portion 1013 (1113), and a predetermined time is necessary before the link-up signal is detected from the condition where the link-up signal is not detected in the reception control portion 1012 (1112) to the condition where the link-up signal is detected. In the 10 Base-T technology using the twist-pair cables, for example, a time of 24 to 72 milliseconds or so is necessary. Therefore, if the loop of the processing 4103, 4104 and 4105 can be executed within a sufficiently shorter period of time than this time, such as about 10 msec, it is possible to know instantaneously the detection of the link-up signal. This loop need not be executed at a higher speed.

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~~The explanation given above explains the process-~~
ing flow starting from Step 4001 in the apparatus A1000 and
the processing flow starting from Step 4101 in the apparatus
B1100. However, both of these flows should be executed in
5 both apparatuses A1000 and B1100. The processing flow that
starts from Step 4001 and transmits spontaneously the link-
up signal to confirm the condition of the mating apparatus
is executed with a predetermined cycle. This cycle is
longer than the cycle that is determined by Step 4002 and
10 the insensitive time of Step 4005, but is a time sufficient
to detect quickly elimination of the line failure. In the
10 Base-T technology using the twist-pair cables, for
example, this time is believed to be preferably about 0.3
to 0.5 seconds or so. When the cycle is longer than this
15 time, the detection is retarded even when the line failure
is solved, and the time necessary for restoring the normal
~~communication becomes longer.~~ *AB*

The processing that starts from Step 4101 and
confirms periodically whether or not the link-up signal,
20 too, is received is executed with a predetermined cycle.
This cycle is longer than the cycle that is determined by
the insensitive time of Step 4102 and the wait time of Step
4105, and is the time sufficient to detect quickly elimina-
tion of the line failure. In the 10 Base-T technology
25 using the twist-pair cables, for example, this cycle is
believed preferably from about 0.3 to about 0.5 seconds or
so. When the cycle is longer than this value, the detec-
tion is retarded even when the line failure is solved, and

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5 be restored.

10 apparatus A1000 and the interface 1110 of the apparatus

15 "normal operation condition, without monitor of operation

the processing shown in Fig. 2. Fig. 7 shows also the state shift from "normal operation condition, with monitor of operation condition" to "operation stop condition, with monitor of operation condition" through "operation state condition, without monitor of operation condition" by the processing shown in Fig. 3. Fig. 7 shows further the state shift from "operation stop condition, with monitor of operation condition" to "normal operation condition, with monitor of operation condition" through "normal operation

condition, without monitor of operation condition" by the processing shown in Fig. 4.

The reasons why the insensitive time described above is necessary will be hereby explained. It will be assumed that both apparatuses A1000 and B1100 are under the operation stop condition where the data communication cannot be made, and both apparatus return from this state to the normal operation condition with the transmission of the link-up signal by the interface 1010 of the apparatus A as being the trigger. This state is shown in Fig. 4. First, the transmission control portion 1013 transmits the link-up signal in accordance with the instruction of the line control portion 1014 of the apparatus A1000. The reception control portion 1113 of the apparatus B1010 receives this link-up signal through the transfer path 1201, and the line control portion 1114 recognizes the link-up signal reception. In contrast, the line control portion 1114 of the apparatus B1100 instructs the transmission control portion 1123 to transmit the link-up signal, and the transmission control portion 1113 transmits the link-up signal. The reception control portion 1012 of the apparatus A1000 receives this link-up signal through the transfer path 1202, and the line control portion 1014 recognizes the reception of the link-up signal. Both apparatuses can restore the normal operation condition after the processing described so far is completed. The reception control portion 1012 (1112) needs the time before it starts receiving the link-up signal and recognizes that

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In the 10 Base-T technology using the twist-pair cable, for example, a pulse called "link pulse" is transmitted in an interval of 16 ± 8 milliseconds during the period in which the data transfer is not executed. It is thus possible to recognize that the transfer path is utilizable, so long as this pulse is steadily received. Therefore, in the restoration sequence described above, the cycle in which the transmission control portion 1012 of the apparatus A1000 transmits the link-up signal and the reception control portion 1013 of the apparatus A1000 receives is maximum about 50 milliseconds. Therefore, when Step 4006 in Fig. 4 is executed immediately after the apparatus A1000 transmits the link-up signal in Step 4004, reaction from the apparatus B1100 is not in time. Consequently, the apparatus A judges that the data communication is not yet ready and stops transmitting the link-up signal with the result that both apparatuses cannot restore the normal operation condition. If latency corresponding to the insensitive time is provided after Step 4004 and then Step 4006 is executed, the apparatus B1100 can recognize the link-up signal and can react with this signal well before the reception recognition processing of the apparatus A1000, and both apparatuses can restore the normal operation condition.

When the operation comes at halt due to the occurrence of any failure under the normal operation condition of both apparatuses A1000 and B1100, this

insensitive time need not be disposed originally. This is the case, for example, where the cable that connects the apparatus A1000 to the apparatus B1010 is cut off and the signal cannot be exchanged. For, one of the transfer paths does not pass the link-up signal due to the occurrence of the failure and both apparatuses are under the operation stop condition. When it is desired to bring the system into the compulsive operation stop condition for some reason or other, the operation stop condition cannot be achieved in some cases unless this insensitive time is disposed in the same way as described above. Let's assume, for example, a case where the line is temporarily brought down for maintenance. Assuming in this case that the apparatus A1000 is under the condition of "normal operation condition, with monitor of operation condition (Step 3001)" of the state shift diagram shown in Fig. 7 and the line is intentionally brought down to achieve the operation stop condition, the apparatus A1000 enters first the condition of "operation stop condition, without monitor of operation condition (Step 3009)". It will be further assumed that setting is made at this time so that the insensitive time of the apparatus A is "0" and the apparatus A instantaneously shifts to "operation stop condition, with monitor of operation condition (Step 4001)", monitors the condition of the line and automatically restores the normal condition. As explained above, it needs time before the mating apparatus B1100 completely reaches the operation stop condition, and the apparatus A1000 is likely to wrongly

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recognize that the apparatus B re-starts the operation, and starts again its operation. In other words, there is the possibility that the apparatus A1000 oscillates in the loop of Step 3001 → Step 3009 → Step 4001 → Step 4008 → Step 5 3001 in the state shift diagram shown in Fig. 7. The insensitive time is set to prevent such an oscillation.

As described above, the transmission control portions 1013 and 1113 of both apparatuses transmit periodically the link-up signal in the predetermined cycle. If 10 the transmission controller 1113 and 1013 of both apparatuses transmit the link-up signal in response to the link-up signal described above, both apparatuses return to the normal operation condition as the failure is judged as being eliminated.

15 When the normal operation condition is restored manually but not automatically after the cause of the failure is eliminated, it may be possible to employ a method that executes the same processing as that of making of power shown in Fig. 2. Alternatively, a process similar 20 to the automatic restoration shown in Fig. 4 may be employed. Both apparatuses A and B cannot always restore the operation condition at the same timing but a certain time lag occurs between them depending on the operation condition. However, the normal restoration can be achieved 25 by either of the methods described above. When the processing similar to that of making of power is executed, the time-up time of the start timers 1017 and 1117 may be equal to the start of the processing of making of power, or

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Next, the second embodiment of the present invention will be explained. In the second embodiment, a dual network system is constituted by using the apparatuses equipped with the line failure detection/reporting system of the present invention explained in the first embodiment so that the operation can be continued by cutting off a failure portion when such a failure occurs.

10 First, the construction of the apparatuses used
in the system of this embodiment will be explained with
reference to Fig. 6. The drawing shows an example of the
apparatus equipped with the line failure detection/
reporting system according to the present invention. The
15 term "apparatus" used herein represents an inter-network
apparatus such as a hub incorporating a computer, a router,
a LAN switch, and so forth, in the same way as in the first
embodiment.

The structural example of the apparatus shown in
20 Fig. 6 has all the functions of the apparatus A1000 used
for explaining the first embodiment with reference to Fig.
1, and includes the following three additional functions.

The first is that the apparatus has n (n : integer more than 1) network interfaces (network interfaces 1010, 1020, ..., 10 n 0). The apparatus shown in Fig. 1 has at least one network interface but in this embodiment, the apparatus shown in Fig. 6 has n network interfaces. Incidentally, Fig. 6 shows only two network interfaces for

5 The second is that each line control portion
1014, 1024 has line operation stop cause storage means
1018, 1028. Each line operation stop cause storage means
1018, 1028 is means for storing the cause of the stop of
the operation when the operation of the line 1210, 1220
0 controlled by its own network interface 1010, 1020 stops.

Fig. 13 shows a table structural example of the

group storage means 1019. Incidentally, the network
interfaces 1010 and 1020 will be hereinafter called merely
the "interfaces 1010 and 1020" in this embodiment, too.
The term "link-up signal" will be used in the same meaning
5 as used in the first embodiment. This example represents
to which group the line control portions 1014, 1024, ...,
10n4 belong. Symbol "-" represents that the line control
member is not the group member. Symbol "○" represents that
the line control portion is the group member and is under
10 the normal operation condition. Symbol "X" represents that
the line control portion is the group member and is under
the operation stop condition due to the failure. Symbol
"△" represents that the line control portion is the group
member but is under the operation stop condition due to the
15 line failure in other groups. For example, the line
control portions 1034, 1044 and 1054 belong as the group
member to the group 2 and are under the normal operation
condition. The line control portions 1014 and 1024 belong
as the group member to the group 1. However, the line
20 control portion 1014 is under the operation stop condition
due to the failure, and the line control portion 1024 is
under the normal operation condition.

In each interface 1010, 1020 of the apparatus
1000 shown in Fig. 6, the processing procedure at the time
25 of making of power is exactly the same as that of the first
embodiment. As to the failure occurring in the line 1210
or 1220 directly coupled with each interface 1010 or 1020,
the differences of the processing procedure from the

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detection of the line failure under the normal operation condition to the operation stop condition, and the processing procedure from the detection of the recovery of the failure under the operation stop condition to the restoration to the normal operation condition, from those of the first embodiment, will be mainly explained. The explanation will be given about the interface 1010 with reference to Figs. 4, 9, 10, 11 and 12.

First, the processing from the detection of a line failure under the normal operation condition to the operation stop condition will be explained. It will be assumed that a failure occurs in the transfer path 1212 connected to the interface 1010 from the state where the interface 1020/line 1220 belonging to the same group as at least the interface 1010/line 1210 and the line 1210 among the interface/line connected to the apparatus 1000 operate normally.

The interface 1010 starts detecting the failure in accordance with the processing procedure shown in Fig. 9, and executes the processing from Step 3001 to Step 3006 in exactly the same way as in the first embodiment. After the line control portion 1014 instructs the transmission control portion 1013 to stop transmission of the link-up signal in Step 3007, the operation stop cause storage portion 1018 stores "failure occurs in own line 1210 and operation stops" in Step 9001. The line control portion 1014 notifies the higher layer control portion 1016 of the occurrence of the failure in Step 9002. Subsequent Steps

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On the other hand, the higher layer control portion 1016 executes the processing in accordance with the

5 flow shown in Fig. 11. Receiving the notice of the occurrence of the failure from the line control portion 1014 of the interface 1010 (Step 11001), the higher layer control portion 1016 looks up the group storage portion 1019 and checks the numbers of all the interfaces/lines belonging to the same group as the interface 1010/line 1210 in which the failure develops. If the line control portion 1014 belongs to a plurality of groups, the numbers of the interfaces/lines belonging to the groups are checked for all the groups to which the line control portion 1014 belongs, and then the instruction to compulsively stop the operation is given to all the corresponding interfaces/lines (Step 11003). The higher layer control portion 1016 updates the table entry of the group storage portion 1019 and stores the stop condition due to the occurrence of the failure and the compulsive stop condition (Step 11004). The higher layer control portion 1016 finishes the processing in this way (Step 11005).

Receiving the instruction to enter compulsively the operation stop condition, the line control portion 1024 executes the processing in accordance with the flow shown in Fig. 10. First, the line control portion 1024 receives the operation stop instruction under the normal condition from the higher layer control portion 1016 (Step 3001).

Consequently, the line control portion 1024 instructs the transmission control portion 1023 to stop transmission of the link-up signal no matter whether or not the failure occurs in the line connected to its on interface 1020 (Step 5 3007). At the same time, the line control portion 1024 causes the line operation stop cause storage means 1028 to store "operation is compulsively stopped due to failure of line 1210 belonging to other interface 1010". The transmission control portion 1023 stops transmitting the link-up 10 signal in accordance with the instruction from the line control portion 1024, and the interface 1020 enters the operation stop condition (Step 3009). In other words, the interface 1020 stops its operation by the instruction from the higher layer control portion 1016 but not by the 15 detection of the failure in its own line. The insensitive time is provided immediately after the operation enters the operation stop condition in both interfaces 1010 and 1020 in the same way as in the first embodiment (Step 3009).

Next, the processing from the operation stop 20 condition to the detection of the recovery of the failure and then to the restoration to the normal operation condition will be explained. It will be assumed hereby that the transmission line 1212 restores the normal condition from the failure under the condition where at 25 least the interface 1010/line 1210 and the interface 1020/line 1220 belonging to the same group as the line 1210 keep stopping the operation due to the failure of the line 121 in accordance with the procedure described above. This

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restoration processing varies depending on the operation stop causes stored in the line operation stop cause storage means of the corresponding line control portion.

After entering the operation stop condition, the interface including the line, in which the failure occurs, examines the content of the line operation stop cause storage means 1018 of the line control portion 1014. In this case, the content reads as "failure occurs in own line 1210 and operation stops". Therefore, the interface 1010 detects the restoration from the failure in exactly the same processing procedure as the processing procedure shown in Fig. 4, and executes the restoration processing. When the line 1210 is restored and reaches the processing 4008 or 4108, the line control portion 1014 reports this effect to the higher layer control portion 1016.

The interface 1020 belonging to the same group as the line 1210/interface 1010 in which the failure occurs, too, enters the operation stop condition, and then examines the content of the line operation stop cause storage portion 1028. In this case, the content reads as "operation is compulsively stopped due to failure of line 1210 belonging to other interface 1010". Therefore, the interface 1020 does not execute the processing procedure shown in Fig. 4 for executing the spontaneous restoration processing. The reason why the interface 1020 does not execute the spontaneous restoration processing is because no failure occurs in itself and if the processing procedure is executed, the interface 1020 is restored instantaneously

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On the other hand, the higher layer control portion 1016 executes the processing in accordance with the flow shown in Fig. 12. Receiving the restoration notice from the interface 1010 that has been under the operation stop condition due to the occurrence of the failure (Step 12001), the higher layer control portion 1016 examines the numbers of all the interfaces/lines belonging to the same group as the recovered interface 1010 while looking up the group storage means 1019 (Step 12002). If the line control portion 1014 belongs to a plurality of groups, the higher layer control portion 1016 examines the numbers of the line control portions of all the groups to which this line control portion 1014 belongs. Thereafter, the higher layer control portion 1016 releases the compulsive operation stop instruction to all the corresponding interfaces/lines, and instructs the re-start of the operation (Step 12003). Here, the interface 1020 corresponds to the object interface that receives the instruction. The higher layer control portion 1016 updates the table entry of the group storage means 1019 and records the normal operation condition. The interface 1020 does not have executed so far the spontaneous restoration processing as described above. Receiving the instruction from the higher layer control portion 1016, however, it executes exactly the same processing procedure as the processing procedure shown in Fig. 4, detects the restoration from the failure and

Fig. 8 shows the state shift of the interfaces by the line failure detection/reporting system of the second embodiment. The drawing shows the state shift of the interface 1110 of the apparatus 1000 explained above.

Fig. 8 shows the state shift from "power source off, operation stop condition" to "normal operation condition, with monitor of operation condition" through "normal operation condition, without monitor of operation condition", and from "power source off, operation stop condition" to "operation stop condition, with monitor of operation condition" through "operation stop condition, without monitor of operation condition", by the processing shown in Fig. 2. Fig. 8 shows also the state shift from "operation stop condition, with monitor of operation condition" to "normal operation condition, with monitor of operation condition" through "normal operation condition, without monitor of operation condition", by the processing shown in Fig. 4. Furthermore, it shows the state shift from "normal operation condition, with monitor of operation condition" to "operation stop condition, with monitor of operation condition" through "operation stop condition, without monitor of operation condition", by the processing shown in Fig. 9 in the case where the cause of the operation stop is the failure of its own line.

Fig. 8 shows further the state shift from "normal operation condition, with monitor of operation condition".

The processing procedure for executing the line failure detection notice by assembling the network by using the apparatus having the additional functions described above will be explained with reference to Fig. 5. Fig. 5 shows a structural example of the network using the apparatuses equipped with the line failure detection/reporting system of the embodiment explained with reference to Fig. 6. First, each portion will be explained.

Each of the apparatuses C5001, D5002, E5003, F5004, G5005, H5006 and J5007 is the apparatus equipped with the line failure detection/reporting system of the present invention explained with reference to Fig. 6.

25 Transfer paths 5101 to 5124 are transfer paths for connecting mutually these apparatuses C5001 to J5007. Arrows of the transfer paths in the drawing represent the data transfer direction. Each odd-numbered transfer path and a

transfer path having a number greater by "1" than the former are the transfer paths that connect the apparatus of the same combination in opposite directions, and the set of these two transfer paths constitutes one line. In this embodiment, the transfer path 5104 for transmitting data from the apparatus C5001 to the apparatus E5003 is called the "transfer path CE5104" and the transfer path 5103 for transmitting the data from the apparatus E5003 to the apparatus C5001, on the contrary, is called the "transfer path EC5103". The pair of the transfer path CE5104 and the transfer path EC5103 is called the "line EC5103" or the "line CE5104". The system shown in Fig. 5 employs the redundant construction, in which the apparatus E5003 and all the lines connected directly to this system constitute the "0" system and the apparatus F5004 and all the lines connected directly to this apparatus constitute the "1" system, by taking the apparatuses E5003, F5004 and the lines connecting to these apparatuses, into specific attention. In Fig. 5, thick lines represent the "0" system and double lines represent the "1" system. Communication is conducted generally by using either one of the "0" and "1" systems with the other being a standby system. When any one of the apparatuses C5001, D5002, E5003 and F5004 is broken, or when any of the lines connecting mutually the apparatuses G5005, H5006, J5007 and the apparatuses E5003 and F5004 is broken, for example, the whole system switches to the standby system and a bypass route is established by utilizing other lines/apparatuses. In consequence, the

Grouping and setting inside each apparatus in this embodiment will be explained. In the apparatus C5001, the line EC5103 belongs to the group "0" and the line FC5105 does to the group "1". In the apparatus D5002, the line ED5111 belongs to the group "0" and the line FD5109 does to the group "1". All the lines directly connected to the apparatus E5003 belong to the group "0" and all the lines directly connected to the apparatus F5004 belong to the group "1". In the apparatus G5005, the line GE5113 belongs to the group "0" and the line GF5119 does to the group "1". In the apparatus H5006, the line HE5115 belongs to the group "0" and the line HF5121 does to the group "1". In the apparatus J5007, the line JE5117 belongs to the group "0" and the line JF5123 does to the group "1". The line 5102 of the apparatus C5001, the line 5107 of the apparatus D5002 and the lines for accommodating computers in the apparatuses G5005, H5006 and J5007, that are not

5 constitute the "1" system described above. Incidentally,
the number for identifying the group need not be always
unified between the apparatuses so long as a consistent
management is made inside each apparatus. However, the
explanation will be hereby given by using the unified
10 numbers.

It will be assumed that only the lines belonging to the group "0" are used in practice by the operation of the afore-mentioned system switching protocol in the system shown in Fig. 5 when all the apparatuses and lines operate normally. In other words, when the data communication needs be made through the apparatus G5005 and the apparatus C5001, the data is assumed to pass through the apparatus G5005, the line GE5113, the apparatus E5003, the line EC5103 and the apparatus C5001. Here, the explanation will be given on the processing when the failure occurs in the transfer path GE5113 between the apparatus E5003 and the apparatus G5005.

It is the apparatus E5003 positioned on the reception side of the transfer path GE5113 that first
25 detects the failure. Detecting the failure, the apparatus E5003 stops transmitting the link-up signal to the transfer path EG5114 in accordance with the state shift shown in Fig. 8, reports the failure to the apparatus G5005, stops

the operation of the interface accommodating the line
EG5114 of the own apparatus and reports the failure occur-
rence to the higher layer control portion inside the
apparatus. Since the line EG5114 belonging to the group
5 "0" stops operating due to the failure, the higher layer
control portion inside the apparatus E5003 instructs all
the other interfaces of the same group inside the apparatus
to compulsively stop the operation. In this case, since
all the interfaces of the apparatus G5003 belong to the
10 group "0", all the lines other than the line EG5114, in
which the failure occurs, are brought compulsively into the
operation stop condition. The apparatuses C5001, D5002,
H5006 and J5007 connected directly to the apparatus G5003
recognize this state as the line failure and stop the
15 operation of the lines EC5103, ED5111, EH5116 and EJ5118,
respectively. The lines that belong to the group "0"
managed internally by the respective higher layer control
portions inside these four apparatuses are only those lines
which are directly connected to the apparatus E5003.
20 Therefore, the processing finishes at this point. However,
the apparatus G5005 detects the operation stop of the
transfer path EG5114 by the apparatus E5003, brings the
interface accommodating the line EG5114 into the operation
stop condition and at the same time, reports the failure
25 occurrence to the higher layer control portion inside the
apparatus. Inside the apparatus G5005, it is only the line
EG5114 that belongs to the group "0" managed by the higher
layer control portion. Therefore, the processing finishes

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The system switching protocol for accomplishing the redundant construction system is accomplished in many cases by a layer that is relatively higher than the physical layer in an OSI (Open System Interconnection) reference model, such as a network layer and a transport layer. Therefore, there is a case where this protocol does not operate smoothly when any failure occurs at only a limited part of the system and a relatively long time is necessary before the whole system is switched. In the present system, however, since the processing is executed at the level of the physical layer, system switching can be made at a high speed and reliably by using the apparatuses according to the present system.

Incidentally, the explanation given above assumes the case where the whole system is switched when the

failure occurs even at one position. However, it may be possible to employ the method of setting the groups so that only the failure portion can be cut off and the system can be switched partially. For example, setting is made so

5 that the lines CE5104 and EG5144 belong to the group "0", the lines CF5106 and FG5120 belong to the group "1", the lines CE5104 and EH5116 belong to the group "2", the lines CF5106 and FH5122 belong to the group "3", the lines CE5104 and EJ5118 belong to the group "4" and the lines CF5106 and

10 FJ5124 belongs to the group "5". Generally, the operation is conducted using the groups "0", "2" and "4". When the failure occurs in the transfer path GE5113 in the same way as in the example given above, only the group "0" is switched to the group "1" while the other groups "2" and

15 "4" continue to operate as such. In this way, it is possible to continue the operation by only switching the group, in which the failure occurs, without switching the whole groups. In this case, the lines CE5104 and CF5114 belong to a plurality of groups, but the processing

20 procedure remains the same.

The explanation given above is based on the assumption that the apparatuses C5001 to J5007 shown in Fig. 5 are the inter-network apparatuses, but they may be computers as described in the starting paragraph of the

25 second embodiment.

The two embodiments of the present invention have thus been explained, and this explanation deals with only the application to the IEEE802.3 system network. However,

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the present invention is not limited to the IEEE802.3 system network, but can be applied to the data transfer system that has independently transfer paths on the transmission side and transfer paths on the reception side, 5 has a failure detection function of the transfer paths on the reception side that can be applied in common to all apparatuses but does not have the failure detection function of the transfer paths on the transmission side that can be applied in common to all the apparatus. When 10 applied, the present invention can reliably conduct the failure detection notice. Even when the data transmission system having the failure detection function of the transfer paths on the reception side and the failure detection function of the transfer paths that can be 15 applied in common to all the apparatuses, the system of the present invention, when applied to such a data transmission system, can process at a high speed and reliably the failure detection notice, and can sometimes witch reliably the processing systems.

20 When link aggregation, that is the technology under the standardization work in IEEE802.3ad, is utilized, a plurality of physical lines for connecting two apparatuses can be aggregated into one logical line and communication can be conducted. Therefore, let's consider a case 25 where the system of the present invention is applied to the lines using this technology. A functional block for executing the failure detection/reporting processing of the first embodiment is provided to each physical line, and a

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functional block for executing the failure detection/
reporting processing of the first or second embodiment is
provided to the logical line that aggregates these physical
lines into one line. The failure of the physical lines is
5 detected and reported by the same method as that of the
first embodiment. In the logical lines, the failure of the
logical line is detected when the failure occurs in all the
physical lines belonging to the logical line and the
communication cannot be continued at the level of the
10 logical line. According to this construction, the logical
line can be operated normally under the state so long as at
least one of the physical lines executes normal communica-
tion. When all the physical lines can no longer conduct
normal communication, the processing can be executed in
15 accordance with the failure detection/reporting system of
the first or second embodiment.

Incidentally, it is possible to accomplish the
whole, or a part, of the functions of the network interface
shown in Figs. 1 and 6 by a one-chip semiconductor
20 integrated circuit.

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